*HISTORY OF THE NAMES CAMBRIAN AND SILURIAN IN GEOLOGY**

IT is proposed in the following pages to give a concise account of the progress of investigation of the lower palæozoic rocks during the last forty years. The subject may naturally be divided into three parts: (1) the history of Silurian and Upper Cambrian in Great Britain from 1831 to 1854; (2) that of the still more ancient palæozoic rocks in Scandinavia, Bohemia, and Great Britain up to the present time, including the recognition by Barrande of the so-called primordial palæozoic fauna; (3) the history of the lower palæozoic rocks of North America.

I.—*Silurian and Upper Cambrian in Great Britain.*

Less than forty years since, the various uncrystalline sedimentary rocks beneath the coal-formation in Great Britain and in continental Europe were classed together under the common name of graywacke or grauwacké, a term adopted by geologists from German miners, and originally applied to sandstones and other coarse sedimentary deposits, but extended so as to include associated argillites and limestones. Some progress had been made in the study of this great Graywacke formation, as it was called, and organic remains had been described from various parts of it; but to two British geologists was reserved the honour of bringing order out of this hitherto confused group of strata, and establishing on stratigraphical and palæontological grounds a succession and a geological nomenclature. The work of these two investigators was begun independently and simultaneously in different parts of Great Britain. In 1831 and 1832, Sedgwick made a careful section of the rocks of North Wales from the Menai Strait across the range of Snowdon to the Berwyn hills, thus traversing in a south-eastern direction Caernarvon, Denbigh, and Merionethshire. Already, he tells us, he had in 1831 made out the relations of the Bangor group (including the Llanberis slates and the overlying Harlech grits), and showed that the fossiliferous strata of Snowdon occupy a synclinal, and are stratigraphically several thousand feet above the horizon of the latter. Following up this investigation in 1832, he established the great Merioneth anticlinal, which brings up the lower rocks on the south-east side of Snowdon, and is the key to the structure of North Wales. From these as a base, he constructed a section along the line already indicated, over Great Arenig to the Bala limestone, the whole forming an ascending series of enormous thickness. This limestone in the Berwyn hills is overlaid by many thousand feet of strata as we proceed eastward along the line of section, until at length the eastern dip of the strata is exchanged for a westward one, thus giving to the Berwyn chain, like that of Snowdon, a synclinal structure. As a consequence of this, the limestone of Bala re-appears on the eastern side of the Berwyns, underlain as before by a descending series of slates and porphyries. These results, with sections, were brought before the British Association for the Advancement of Science at its meeting at Oxford in 1832; but only a brief and imperfect account of the communication of Sedgwick on this occasion appears in the Proceedings of the Association. He did not at this time give any distinctive name to the series of rocks in question (L.E. and D. Philos. Mag. (1854) IV., viii. 495).

Meanwhile in the same year, 1831, Murchison began the examination of the rocks on the river Wye, along the southern border of Radnorshire. In the next four years he extended his researches through this and the adjoining counties of Hereford and Salop, distinguishing in this region four separate geological formations, each characterised by peculiar fossils. These formations were moreover traced by him to the south-westward across the counties of Brecon and Caermarthen; thus forming a belt of fossiliferous rocks stretching from near Shrewsbury to the mouth of the river Towey, a distance of about 100 miles along the north-west border of the great Old Red Sandstone formation, as it was then called, of the West of England.

The results of his labours among the rocks of this region for the first three years were set forth by Murchison in two papers presented by him to the Geological Society of London in January 1834 (Proc. Geol. Soc. ii., 11). The formations were then named as follows in descending order:—(1) Ludlow, (2) Wenlock, constituting together an upper group; (3) Caradoc, (4) Llandeilo (or Builth), forming a lower group. The Llandeilo formation, according to him, was underlain by what he called the Longmynd and Gwastaden rocks. The non-fossiliferous strata of the Longmynd hills in Shropshire were described as rising up to the east from beneath the Llandeilo rocks; and as appearing again in South Wales, at the same geological horizon, at Gwastaden in Breconshire, and to the west of Llandovery in Caermarthenshire; constituting an underlying series of contorted slaty rocks many thousand feet in thickness, and destitute of organic remains. The position of these rocks in South Wales was, however, to the north-west, while the strata of the Longmynd, as we have seen, appear to the east of the fossiliferous formations.

In the "Philosophical Magazine" for July, 1835, Murchison gave to the four formations above named the designation of Silurian, in allusion, as is well known, to the ancient British tribe of the Silures. It now became desirable to find a suitable name for the great inferior series, which, according to Murchison, rose from beneath his lowest Silurian formations to the north-west, and appeared to be widely spread in Wales. Knowing that Sedgwick had long been engaged in the study of these rocks, Murchison, as he tells us, urged him to give them a British geographical name. Sedgwick accordingly proposed for this great series of Welsh rocks, the appropriate designation of Cambrian, which was at once adopted by Murchison for the strata supposed by him to underlie his Silurian system. (Murchison, Anniv. Address, 1842; Proc. Geol. Soc. iii., 641.) This was almost simultaneous with the giving of the name of Silurian; for in August 1835, Sedgwick and Murchison made communications to the British Association at Dublin on Cambrian and Silurian Rocks. These, in the Volume of Proceedings (pp. 59, 60) appear as a joint paper, though from the text they would seem to have been separate. Sedgwick then described the Cambrian rocks of North Wales as including three divisions: 1. The Upper Cambrian, which occupies the greater part of the chain of the Berwyns, where, according to him, it was connected with the Llandeilo formation of the Silurian. To the next lower division, Sedgwick gave the name of Middle Cambrian, making up all the higher mountains of Caernarvon and Merionethshire, and including the roofing-slates and flagstones of this region. This middle group, according to him, afforded a few organic remains, as at the top of Snowdon. The inferior division, designated as Lower Cambrian, included the crystalline rocks of the south-west coast of Caernarvon and a considerable portion of Anglesea, and consisted of chloritic and micaceous schists, with slaty quartzites and subordinate beds of serpentine and granular limestone; the whole without organic remains.

These crystalline rocks were, however, soon afterwards excluded by him from the Cambrian series; for in 1838 (Proc. Geol. Soc. ii., 679) Sedgwick describes further the section from the Menai Strait to the Berwyns, and assigns to the chloritic and micaceous schists of Anglesea and Caernarvon a position inferior to the Cambrian, which he divides into two parts; viz., Lower Cambrian, comprehending the old slate series, up to the Bala limestone beds; and Upper Cambrian, including the Bala beds and the strata above them in the Berwyn chain, to which he gave the name of the Bala group. The dividing line between the two portions was subsequently extended downwards by Sedgwick to the summit of the Arenig slates and porphyries. The lower division was afterwards subdivided by him into the Bangor group (to which the name of Lower Cambrian was henceforth to be restricted), including the Llanberis roofing-slates and the Harlech grits or Barmouth sandstones; and the Festiniog group, which included the Lingula flags and the succeeding Tremadoc slates.

In the communication of Murchison to the same Dublin meeting, in August 1835, he repeated the description of the four formations to which he had just given the name of Silurian; which were, in descending order, Ludlow and Wenlock (Upper Silurian), and Caradoc and Llandeilo (Lower Silurian). The latter formation was then declared by Murchison to constitute the base of the Silurian system, and to offer in many places in South Wales distinct passages to the underlying slaty rocks, which were, according to him, the Upper Cambrian of Sedgwick.

Meanwhile, to go back to 1834, we find that after Murchison had, in his communication to the Geological Society, defined the relation of his Llandeilo formation to the underlying slaty series, but before the names of Silurian and Cambrian had been given to these respectively, Sedgwick and Murchison visited together the principal sections of these rocks from Caermarthenshire to Denbighshire. The greater part of this region was unknown to Sedgwick, but had already been studied by Murchison, who interpreted the sections to his companion in conformity with the scheme already given; according to which the beds of the Llandeilo were underlain by the slaty rocks which appear along their north-western border. When, however, they entered the region which had already been examined by Sedgwick, and reached the section on the east side of the Berwyns, the fossiliferous beds of Meifod were at once pronounced by Murchison to be typical Caradoc, while others in the vicinity were regarded as Llandeilo. The beds of Meifod had, on palæontological grounds, been by Sedgwick identified with those of Glyn Ceirog, which are seen to be immediately overlain by Wenlock rocks. These determinations of Murchison were, as Sedgwick tells us, accepted by him with great reluctance, inasmuch as they involved the upper part of his Cambrian section in most perplexing difficulties. When, however, they crossed together the Berwyn chain to Bala, the limestones in this locality were found to contain fossils nearly agreeing with those of the so-called Caradoc of Meifod. The examination of the section here presented showed, however, that these limestones are overlain by a series of several thousand feet of strata bearing no resemblance, either in fossils or in physical characters, to the Wenlock formation which overlies the Caradoc beds of Glyn Ceirog. This series was, therefore, by Murchison supposed to be identical with the rocks which, in South Wales, he had placed beneath the Llandeilo, and he expressly declared that the Bala group could not be brought within the limits of his Silurian system. It may here be added that in 1842 Sedgwick re-examined this region, accompanied by that skilled palæontologist, Salter, confirming the accuracy of his former sections, and showing moreover by the evidence of fossils that the beds of Meifod, Glyn Ceirog, and Bala, are very nearly on one parallel. Yet, with the evidence of the fossils before him, Murchison, in 1834, placed the first two in his Silurian system, and the last deep down in the Upper Cambrian; and consequently was aware that on palæontological grounds it was impossible to separate the lower portion of his Silurian system from the Upper Cambrian of Sedgwick. (These names are here used for convenience, although we are speaking of a time when they had not been applied to designate the rocks in question.)

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This fact was repeatedly insisted upon by Sedgwick, who, in the Syllabus of his Cambridge lectures, published very early in 1837, enumerated the principal genera and species of Upper Cambrian fossils, many of which were by him declared to be the same with those of the Lower Silurian rocks of Murchison. Again, in enumerating in the same Syllabus the characteristic species of the Bala limestone, it is added by Sedgwick: "all of which are common to the Lower Silurian system." This was again insisted upon by him in 1838 and 1841. (Proc. Geol. Soc. ii. 679; iii. 548.) It was not until 1840 that Bowman announced the same conclusion, which was reiterated by Sharpe in 1842. (Ramsay, Mem. Geol. Sur. iii., part 2, p. 6.)

In 1839 Murchison published his "Silurian System," dedicated to Sedgwick, a magnificent work in two volumes quarto, with a separate map, numerous sections, and figures of fossils. The succession of the Silurian rocks, as there given, was precisely that already set forth by the author in 1834, and again in 1835; being, in descending order, Ludlow and Wenlock, constituting the Upper Silurian, and Caradoc and Llandeilo (including the Lower Llandeilo beds or Stiper-stones), the Lower Silurian. These are underlain by the Cambrian rocks, into which the Llandeilo was said to offer a transition marked by beds of passage. Murchison in fact declared that it was impossible to draw any line of separation, either lithological, zoological, or stratigraphical, between the base of the Silurian beds (Llandeilo) and the upper portion of the Cambrian, the whole forming, according to him, in Caermarthenshire, one continuous and conformable series from the Cambrian to the Ludlow. ("Silurian System," pp. 256, 358.) By Cambrian in this connection we are to understand only the Upper Cambrian or Bala group of Sedgwick, as appears from the express statement of Murchison, who alludes to the Cambrian of Sedgwick as including all the older slaty rocks of Wales, and as divided into three groups, but proceeds to say that in his present work (the "Silurian System") he shall notice only the highest of these three.

Since January 1834, when Murchison first announced the stratigraphical relations of the lower division of what he afterwards called the Silurian system, the aspect of the case had materially changed. This division was no longer underlain, both to the east in Shropshire and to the west in Wales, by a great unfossiliferous series. His observations in the vicinity of the Berwyn hills with Sedgwick in 1834, and the subsequently published statements of the latter had shown, that this supposed older series was not without fossils; but on the contrary, in North Wales, at least, held a fauna identical with that characterising the Lower Silurian. Hence the assertion of Murchison in his "Silurian System," in 1839, that it was not possible to draw any line of demarcation between them. The position was very embarrassing to the author of the "Silurian System," and for the moment, not less so to the discoverer of the Upper Cambrian series. Meanwhile, the latter, as we have seen, in 1842 re-examined with Salter his Upper Cambrian sections, in North Wales, and satisfied himself of the correctness, both structurally and palæontologically, of his former determinations. Murchison, in his Anniversary Address as President of the Geological Society in 1842, after recounting, as we have already done, the history of the naming by Sedgwick in 1839 of the Cambrian series, which Murchison supposed to underlie his Silurian system, proceeded as follows:—"Nothing precise was then known of the organic contents of this lower or Cambrian system, except that some of the fossils contained in its upper members in certain prominent localities were published Lower Silurian species. Meanwhile, by adopting the word Cambrian, my friend and myself were certain that whatever might prove to be its zoological distinctions, this great system of slaty rocks being evidently inferior to those zones which had been worked out as Silurian types, no ambiguity could hereafter arise. . . . In regard, however, to a descending zoological order, it still remained to be proved whether there was any type of fossils in the mass of the Cambrian rocks different from those of the Lower Silurian series. If the appeal to nature should be answered in the negative, then it was clear that the Lower Silurian type must be considered the true base of what I had named the protozoic rocks; but if characteristic new forms were discovered, then would the Cambrian rocks, whose place was so well established in the descending series, have also their own fauna, and the palæozoic base would necessarily be removed to a lower horizon." If the first of these alternatives should be established, or in other words, if the fauna of the Cambrian rocks was found to be identical with that of the Lower Silurian, then, in the author's language, "the term Cambrian must cease to be used in zoological classification, it being, in that sense, synonymous with Lower Silurian." That such was the result of palæontological inquiry, Murchison proceeded to show, by repeating the announcements already made by Sedgwick in 1837 and 1838, that the collections made by the latter from the great series of fossiliferous strata in the Berwyns, from Bala, from Snowden, and other Cambrian tracts, were identical with the Lower Silurian forms. These strata, it was said, contain throughout "the same forms of *Orthis* which typify the Lower Silurian rocks." It was further declared by Murchison in this address that researches in Germany, Belgium, and Russia led to the conclusion that the "fossiliferous strata characterised by Lower Silurian Orthidæ are the oldest beds in which organic life has been detected." (Proc. Geol. Soc. iii. 641, &c.) The Orthids here referred to are, according to Salter, *Orthis calligramma*, Dalm, and its varieties. (Mem. Geol. Survey iii, part 2, 335-337.)

Meanwhile Sedgwick's views and position began to be misrepresented. In 1842 Mr. Sharpe, after calling attention to the fact that the fossils of the Bala limestone were, as Sedgwick had long before shown, identical with those of Murchison's Lower Silurian, declared that Sedgwick had placed the Upper Cambrian, in which the Bala beds were included, beneath the Silurian, and that this determination had been adopted by Murchison on Sedgwick's authority. (Proc. Geol. Soc. iv. 10.) This statement Murchison suffered to pass uncorrected in a complimentary review of Sharpe's paper in his next annual address (1843.) In his "Siluria," 1st edition, p. 25 (1854), he speaks of the term Cambrian as applied (in 1835) by Sedgwick and himself "to a vast succession of *fossiliferous* strata containing undescribed fossils, the whole of which were supposed to rise up from beneath well-known Silurian rocks. The Government geologists have shown that this *supposed* order of superposition was erroneous," &c. The italics are the author's. Such language, coupled with Mr. Sharpe's assertion noticed above, helped to fix upon Sedgwick the responsibility of Murchison's error. Although the historical sketch which precedes clearly shows the real position of Sedgwick in the matter, we may quote further his own words:—"I have often spoken of the great Upper Cambrian group of North Wales as inferior to the Silurian system, . . on the sole authority of the Lower Silurian sections, and the author's many times repeated explanations of them before they were published. So great was my confidence in his work, that I received it as perfectly established truth that his order of superposition was unassailable. . . . I asserted again and again that the Bala limestone was near the base of the so-called Upper

Cambrian group. Murchison asserted and illustrated by sections the unvarying fact that his Llandeilo flag was superior to the Upper Cambrian group. There was no difference between us until his Llandeilo sections were proved to be wrong." (Philos. Mag. IV. viii. 506.) That there must be a great mistake in Sedgwick's or in Murchison's sections was evident, and the Government surveyors, while sustaining the correctness of those of Sedgwick, have shown the sections of Murchison to have been completely erroneous.

The first step towards an exposure of the errors of the Silurian sections is, however, due to Sedgwick and McCoy. In order better to understand the present aspect of the question, it will be necessary to state in a few words some of the results which have been arrived at by the Government surveyors in their studies of the rocks in question, as set forth by Ramsay in the Memoirs of the Geological Survey. In the section of the Berwyns, the thin bed of about twenty feet of Bala limestone, which (as originally described by Sedgwick) they have found outcropping on both sides of the synclinal chain, is shown to be intercalated in a vast thickness of Caradoc rocks; being overlain by about 3,300 and underlain by 4,500 feet of strata belonging to this formation. Beneath these are 4,500 feet additional of beds described as Llandeilo, which rest unconformably upon the Lingula-flags just to the west of Bala; thus making a thickness of over 12,000 feet of strata belonging to the Bala group of Sedgwick. A small portion of rocks referred to the Wenlock formation occupies the synclinal above mentioned. (Memoirs, III. part 2, 214,222.) The second member, in ascending order, of the Silurian system, to which the name of Caradoc was given by him in 1839, was originally described by Murchison under the names of the Horderly and May Hill sandstone. The higher portions of the Caradoc were subsequently distinguished by the Government surveyors as the Lower and Upper Llandovery rocks; the latter (constituting the May Hill sandstone, and known also as the Pentamerus beds) being by them regarded as the summit of the Caradoc formation. In 1852, however, Sedgwick and McCoy showed from its fauna that the May Hill sandstone belongs rather to the overlying Wenlock than to the Caradoc formation, and marks a distinct palæontological horizon.

This discovery led the geological surveyors to re-examine the Silurian sections, when it was found by Aveline that there exists in Shropshire a complete and visible want of conformity between the underlying formations and the May Hill sandstone; the latter in some places resting upon the nearly vertical Longmynd rocks, and in others upon the Llandeilo flags, the Caradoc proper or Bala group, and the Lower Llandovery beds. Again, in South Wales, near Builth, the May Hill sandstone or Upper Llandovery rests upon Lower Llandeilo beds; while at Noeth Grug the overlying formation is traced transgressively from the Lower Llandovery across the Caradoc to the Llandeilo. These important results were soon confirmed by Ramsay and by Sedgwick. (Ibid, 4, 236). The May Hill sandstone often includes, near its base, conglomerate beds made up of the ruins of the older formation. To the north-east, in the typical Silurian country, it is of great thickness and continuity, but gradually thins out to the south-west. There exists, moreover, another region where not less curious discoveries were made. About forty miles to the eastward of the typical region in South Wales appear some important areas of Silurian rocks. These are the Woolhope beds, appearing through the Old Red Sandstone, and the deposits of Abberley, the Malverns and May Hill rising along its eastern border, and covered along their eastern base by the newer Mesozoic sandstone. The rocks of these localities were by Murchison in his "Silurian System" described as offering the complete sequence. When however it was found that his Caradoc included two unconformable series, examination showed that there was no representative of the older Caradoc or Bala group in these eastern regions, but that the so-called Caradoc was nothing but the Upper Llandovery or May Hill sandstone. The immediately underlying strata, which Murchison had regarded as Llandeilo, or rather as the beds of passage from Llandeilo to Cambrian, and had compared with the north-west passage of the Caermarthenshire sections (Syl. Sys. 416), have since been found to be much more ancient deposits, of Middle Cambrian age, which rests upon the crystalline hypozoic rocks of the Malverns, and are uncomformably overlain by the May Hill sandstone. We shall again revert to this region, which has been carefully studied and described by Prof. John Phillips. (Mem. Geol. Sur. II., part 1.)

T. STERRY HUNT

(*To be continued*)

SCIENTIFIC SERIALS

THE *Révue Scientifique*, Nos. 33—42. The first article in these numbers is by Prof. Huxley, on Yeast.—The conclusion is arrived at of M. de Quatrefages' course of lectures on Anthropology, at the Museum of Natural History at Paris.—M. de Fonvielle contributes an article on Balloon Observations. In No. 34. M. Léon Le Fort, Professor to the Faculty of Medicine at Paris, furnishes an account of military surgery in the Austrian army.—Among the contributions from foreign sources is a report of M. Vogel's spectroscopic observations of the planets made in 1871 at the observatory of Bothkamp.—No. 35 contains an interesting lecture, delivered at the University of Friberg-in-Brisgau, by M. Ecker, on the struggle for existence in the character and in the life of nations.—In No. 36 is commenced a report, continued in subsequent numbers, of M. Claude Bernard's course of lectures at the College of France on Animal Heat. A translation is given of a paper by Prof. Harting, of Utrecht, on the artificial production of organic calcareous formations. There are also reports of the proceedings of English and other foreign scientific societies.—In No. 37 the most interesting paper is one by Dr. Onimus, on the consecutive phenomena attendant on the removal of the brain, and on the movements of rotation, illustrated with drawings of frogs and birds, on which the operation had been performed, to show the action.—No. 38 contains a report of Prof. Virchow's address to the Congress of German Naturalists and Physicians at Rostock, on Science in the national life of Germany. Sir William Thomson's paper on the Size of Atoms is translated from an early number of this journal. M. Papillon has an article in support of M. Wurtz's aphorism, "Chemistry is a French science, constituted by Lavoisier," in reply to English and German attacks.—No. 39 commences with an important article by M. P. Lorain, on Reform in the Higher Instruction. A translation is given of M. R. Wolf's lecture at the University of Zurich on Solar Spots, and of Neumayer's paper contributed to the Vienna *k. k. Geologische Reichsanstalt* on the Jurassic Basins.—In No. 40 M. Le Fort supplements his previous paper by an additional one on Military Surgery in the Prussian army. This and the following number are partially filled with further reports of the Rostock meeting of German naturalists and physicians.—In No. 41 we find also a lecture by M. Lereboullet at the School of Military Health at Montpellier on the Spinal Column.—No. 42 contains a report of M. Blanchard's address to the Annual Congress of the Learned Societies of the Departments at the Sorbonne. M. Paul de Saint Robert contributes a paper with the suggestive title, "Qu'est ce que la force?" There are also a number of reports of the proceedings of foreign societies.

THE *Journal of Botany* for April commences with an interesting article by Prof. Babington on the *Anacharis alsinastrum* or Canadian water-weed. He shows clearly that there are two series of plants closely resembling each other in appearance, of which one series has perfect triandrous flowers, and the other has incomplete diœcious flowers, of which the males are nearly or quite sessile, and have the curious habit of becoming detached when the pollen is ripe, and floating freely about on the surface of the water, and shedding their pollen there. To the first series belongs the *Elodea* of South America; to the second, *Anacharis* and *Hydrilla*. *Anacharis* would therefore appear to be the true genus to which the English (introduced) plant belongs, as given by Hooker, but not by Bentham and Syme.—Mr. Baker gives one of his useful synoptical revisions of the Cape species of *Anthericum*; and Prof. Thiselton Dyer a history of the substance known as "Australian Caoutchouc," and a valuable account of the mode of germination of *Tropæolum*, which is characteristic rather of endogens than of exogens.

Annalen der Chemie und Pharmacie, January 1872. This number commences with a paper by Max Ascher on the trisubstitution derivation of benzine; this is an attempt to establish the constitution of some of these bodies, but at present, however, it has not been entirely successful.—The next paper is by Linnemann and Zotta "On the reduction of formic acid to formaldehyde and methyl alcohol;" the authors followed exactly the same process as was described by Lieben and Rossi some time since, and which has already been noticed in these pages. The next three communications are by Linnemann "On normal propyl alcohol, its compounds and its conversion into isopropyl alcohol." The author prepared the normal alcohol in two ways—by the action of nascent hydrogen on propionic anhydride, and by obtaining the aldehyde by distillation of calcic